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No. 816

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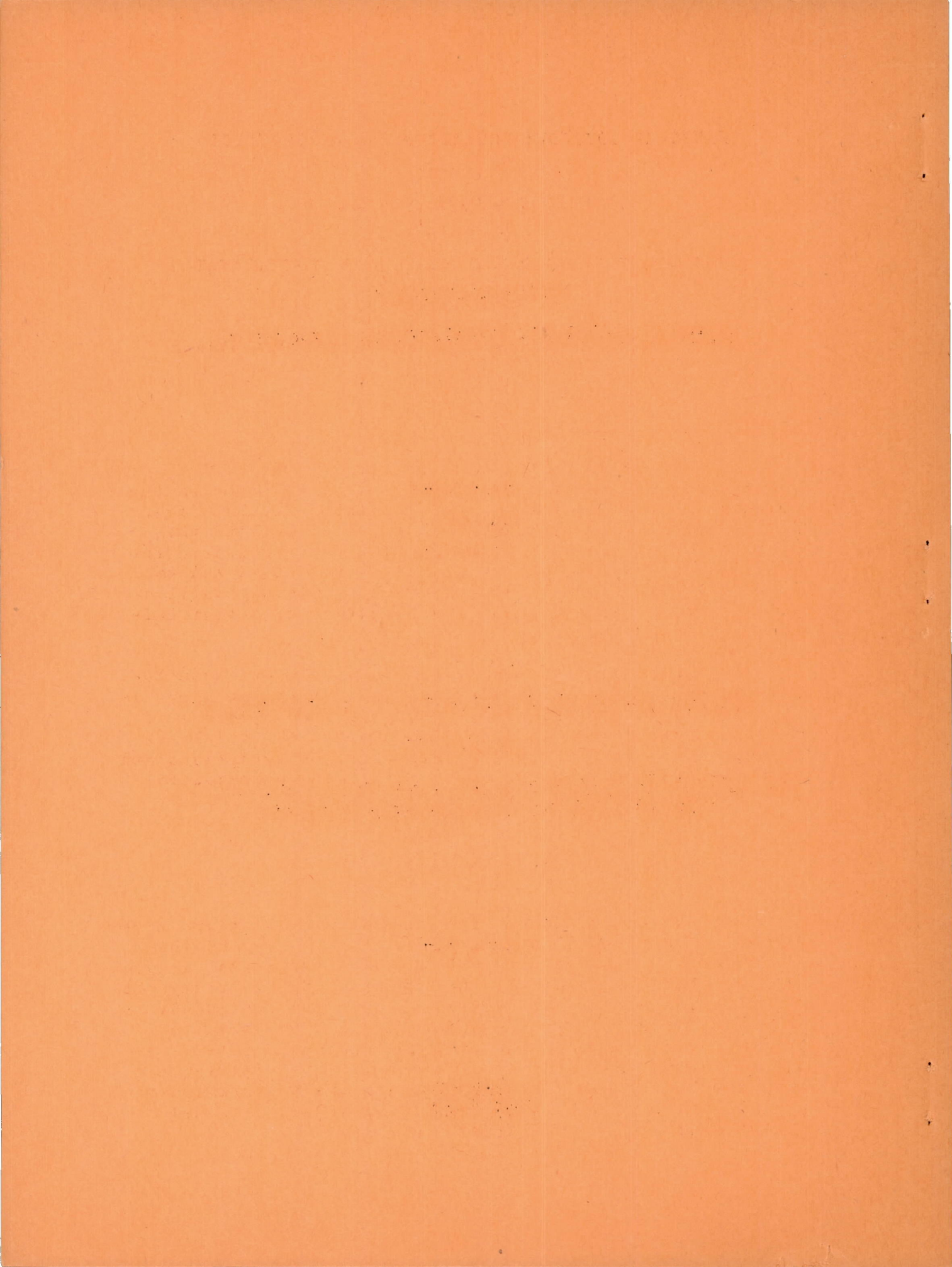
A-75 ENGINE

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SUMMARY

An investigation has been started by the NACA to de-
termine the performance of a small airplane with two Con-
tinental A-75 air-cooled engines enclosed in the wings.
The object of the reported tests was to determine the
quantity of air and the pressure difference required for
satisfactory cooling of the engine at sea level and at
altitude. The engine cylinders were completely baffled
and the steps taken to obtain a satisfactory set of baf-
fles are described.

The position of the carburetor and the oil sump be-
low the crankcase of the Continental A-75 engine appreci-
ably increases the thickness of the engine. The use of
modified intake and oil systems decreases the thickness
of the engine to that of the crankcase. Descriptions and
test results are given of three modified intake-manifold
systems.

INTRODUCTION

The exposed wing nacelles of modern multiengine air-
planes account for 10 to 25 percent of the drag of the
airplane. As other sources of parasite resistance gradu-
ally are being eliminated, the necessity for reducing the
engine-nacelle drag has become increasingly important. A
refinement for multiengine airplanes is the removal of
the nacelles from the wings and the enclosure of the com-
plete power plant within the wing. An investigation has
been started by the NACA to determine the performance of
a small airplane with two Continental A-75 air-cooled
engines enclosed in the wings.

Several problems are introduced with this type of engine installation. The quantity of cooling air required by the engine must be small in order that the wing ducts may be of such size as to introduce little interference with the aerodynamic characteristics of the wing. Accordingly, the baffles around the cylinder must be of such a design that the cooling air can be used to the greatest advantage. Because no air will be flowing over the crankcase, a provision has to be made to cool the oil. The exhaust pipes are a fire hazard when placed in the wing, and some method of cooling them is required. The oil sump and the carburetor of the Continental A-75 engine about double the thickness of the engine.

The object of the present paper is to present the steps taken in developing a set of baffles for a Continental A-75 engine, suitable for use in the wing of the projected airplane, and the cooling and performance characteristics of the engine at sea level and at altitude with these baffles. A description of the system used to cool the oil and tests with this system are given. A new manifold system designed and tested for use with the engines in the wings is described.

APPARATUS

The Continental A-75 engine (fig. 1) used in these tests is a four-cylinder, horizontally opposed piston, air-cooled engine rated 75 brake horsepower at 2600 rpm with a partial pressure of dry air of 29.92 inches of mercury and a temperature of 60° F in the manifold. The bore and the stroke are $3\frac{7}{8}$ and $3\frac{5}{8}$ inches, respectively, and the compression ratio is 6.3. The displacement is 171 cubic inches and the recommended C.F.R. octane rating for the fuel was 72 or more. The engine was mounted in the laboratory on a specially constructed stand and was driven by an electric dynamometer.

The cylinders were enclosed in sheet-metal baffles (fig. 2) that fitted tightly against the fins except at the entrance and the exit of the baffles. The engines in the projected airplane are to be used as pushers and for that reason the air is introduced to the cylinders from the gear end of the engine. The baffles did not project above or below the crankcase because the wing thickness

of the airplane in which the engine would be installed was just slightly greater than the crankcase thickness. The baffles when first made had many flanged joints held together with bolts. Later, most of the joints of the baffles were welded, for reasons to be presented, and the welded baffles are the ones shown in figure 2. The entrance and the exit areas of a baffle around any one cylinder were made approximately 1.6 times the free-flow area between the fins.

The cylinder cooling system consisted of an orifice tank, used for measuring the quantity of air, a centrifugal blower, and a surge tank. The orifice tank was connected to the blower, and air ducts connected the surge tank to the blower and to the baffles. A surge tank was installed in the inlet system above the engine to reduce pulsations, and a thin-plate orifice was used to measure the air consumption. The engine power was absorbed by the electric dynamometer and the torque was measured by dial scales. Standard test-engine equipment was used in measuring engine speed and fuel consumption. The engine set-up is shown in figure 3 and a diagrammatic sketch of the set-up is shown in figure 4.

Iron-constantan thermocouples and a potentiometer were used for measuring the cylinder temperatures. The thermocouples were made of 0.016-inch diameter wire, enameled and silk-covered, and were peened into the cylinder head and spot-welded to the barrel. The temperatures of cylinder 1 (see fig. 1 for cylinder locations) were measured with 8 thermocouples on the cylinder head, 6 on the barrel, and 1 on the flange. (See fig. 5.) Thermocouples were similarly located on cylinder 4 except that, in place of a thermocouple below the bottom spark plug as thermocouple 15 on cylinder 1, a gasket-type thermocouple was placed under the top spark plug. A thermocouple was also located in the rocker box of cylinder 4 (fig. 5). Thermocouples were placed on cylinders 2 and 3 at the same locations as thermocouples 1, 14, and 15 on cylinder 1.

The temperature of the inlet cooling air was measured in the duct before the baffles. The temperatures of the cooling air at the outlet of each barrel and head were separately measured. Each temperature was determined by a multiple thermocouple consisting of two thermocouples connected in series.

The cold junctions of all thermocouples were located in an insulated box. Liquid thermometers were used for measuring the cold-junction temperature, the inlet-air temperatures at the thin-plate orifices and in the inlet manifold near the cylinder, and the oil-in temperature. Iron-constantan thermocouples were used for measuring the temperature of the oil in the rocker box of cylinder 4 and in the oil sump.

The pressure drop across the cylinders was measured by total-pressure tubes placed in the air ducts before the baffles. The tubes were connected to water-filled manometers. An inclined, water-filled tube was used to measure the pressure in the orifice tank and mercury manometers were used to measure the engine inlet pressure and the pressure in an exhaust pipe 1 inch from the port opening. The air quantity to the engine was determined with a thin-plate orifice in conjunction with a multiple manometer that indicated the total pressure in inches of mercury and the pressure drop across the orifice in inches of water.

METHODS

Preliminary tests were conducted on the engine to determine the quantity of air required to obtain adequate cooling with wide-open throttle and an engine speed of 2600 rpm. Various changes were then made in the baffles and in the oil-cooling system to decrease the quantity of air required for cooling.

After the quantity of cooling air had been decreased as much as possible, tests were made in order that the performance and the cooling characteristics of the engine for any atmospheric condition could be predicted. Equations have been derived (reference 1) in which the average head and barrel temperatures of the cylinder are given as functions of the engine and the cooling variables. The equation for the head may be written as follows:

$$\frac{T_h - T_a}{T_g - T_h} = K_1 \frac{I^{n'}}{\left(\Delta p \rho / \rho_0\right)^m} \tag{1}$$

where

T_h average cylinder-head temperature, $^\circ F$

T_a inlet temperature of cooling air, $^\circ F$

T_g effective gas temperature, $^\circ F$

I indicated horsepower

Δp pressure difference across cylinder, including loss out exit of baffle, inches of water

ρ average density of cooling air entering and leaving fins, pound-second^2 per foot^4

ρ_o density of air at 29.92 inches of mercury and 70° F, pound-second^2 per foot^4

n', m, and K_1 constants for a given engine

A similar equation may be written for the barrel. Equations also have been derived (reference 2) for temperatures at individual points on the cylinder head and barrel. Thus, for a temperature at a given location on the head the following equation may be written:

$$\frac{\left(\Delta p \rho / \rho_o\right)}{I^{n'}} \frac{\left(T_{h_x} - T_a\right)}{\left(T_g - T_{h_x}\right)} = f_1\left(\Delta p \rho / \rho_o\right) \tag{2}$$

where T_{h_x} is the temperature of the cylinder head at some one point. The other symbols have the same significance as in equation (1) and m, n', and T_g have the same values as in equation (1). A similar equation may be written for individual barrel temperatures. For most thermocouple locations it has been found that $f_1\left(\Delta p \rho / \rho_o\right)$ can be replaced by a constant. The effective gas temperature, T_g, varies with spark setting, carburetor-air temperature, exhaust back pressure, and fuel-air ratio; for the present tests these variations may be neglected except that with fuel-air ratio. The results obtained from a large number of tests for several cylinders (references 1, 2, and 3) led to a choice of 1150° F for T_g

for the head and $600°$ F for the barrel with a maximum
power mixture.

The cylinder temperatures are expressed in these
equations in terms of $\Delta p\rho/\rho_0$, T_a, and I. These rela-
tionships are used to determine the pressure drop re-
quired to cool the engine to a given temperature when the
altitude and the horsepower output are known.

In order to determine the constants of equations (1)
and (2) and the constants for similar equations for the
barrel and to determine the variation of T_g with fuel-
air ratio, it is necessary to vary in turn the pressure
drop, the indicated horsepower, and the fuel-air ratio
while the other engine and cooling conditions are held
constant. Such tests were conducted on the Continental
A-75 engine. In addition, tests were conducted at wide-
open throttle with a maximum power mixture over a range
of engine speeds from 1600 to 2600 rpm to determine the
variation of mean effective pressure and specific fuel
consumption with engine speed. A series of tests was
made at wide-open throttle and 2600 rpm to determine the
variation of power and specific fuel consumption for a
range of fuel-air ratios. These tests are needed to pre-
dict brake fuel consumption and brake horsepower at alti-
tude for mixtures other than maximum-power mixture.

For a given throttle setting, the power an engine
develops usually increases as the cylinder temperatures
decrease. Because the power required for cooling will
increase with an increase in cooling-air weight, it is of
interest to determine whether the net brake horsepower
(brake horsepower minus power for cooling) will increase
as the temperature decreases. Tests were therefore made
at full throttle and at an engine speed of 2600 rpm with
maximum-power mixture and maximum-economy mixture to find
the variation of net brake horsepower with quantity of
cooling air.

Gasoline conforming to the Army Specification No.
2-92, grade 100 (100 octane number, Army method), was used
for most of the tests in order to avoid any detonation
that might occur during the high-power runs. A few tests
were made with a commercial automobile gasoline of approxi-
mately 78 octane number to compare the performance of the
engine using this fuel with the performance using 100
octane fuel.

The engine horsepowers given in this report are all observed values except those in predicted performance charts. The friction horsepower was determined by motoring the engine at the inlet pressures and the speeds used in the power runs. The method of computing the results is fully described in reference 1.

PRELIMINARY TESTS

The various sections of the first baffles were bolted together. A large gap was left between the baffle and the cylinder wall around the rocker boxes at the point marked A in figure 6 so that air flowed over the rocker boxes. The baffles at the point marked B (fig. 6) fitted tightly against the cylinder wall so that little air flowed over the flanges. Water was sprayed over the oil sump (fig. 19(a)) to cool the oil.

The results of the tests with the preliminary baffles, at wide-open throttle and 2600 rpm, are given in table I, run 36. The hottest head, barrel, and flange temperatures were on cylinder 4 at the positions of thermocouples 14, 4, and 1, respectively, shown on figure 5. The head and the barrel temperatures were considered satisfactory but the flange temperature was considered slightly high and the quantity of air was too great. The air was leaking very badly through the bolted joints.

Almost all of the joints in the baffles were then welded and the gap at point A (fig. 6) was reduced to a mere slit. The results with these baffles are shown in table I, run 47. The quantity of cooling air appreciably decreased compared with the quantity needed with the preliminary baffles. The head temperature remained the same and the barrel temperature decreased 8° F. The temperature in the rocker box of cylinder 4, thermocouple 31 (fig. 5), increased from 276° to 312° F because less air was flowing over the rocker boxes with the welded baffles than with the preliminary baffles. All of the temperatures were considered satisfactory except the flange temperature, which was still high. The slit between the baffles and the cylinder wall around the rocker boxes was next closed with a cementing mixture to determine the decrease in cooling-air weight. The results are shown in table I, run 48. The rocker-box temperature increased from 312° to 330° F, but all of the temperatures were

considered satisfactory except the oil-in temperature and the hottest flange temperature.

The water spray was next removed from the oil sump, and an oil cooler and pump were placed in series with the sump. Oil was circulated from the sump through the cooler, which was placed in a tank of water as shown in figures 3 and 4, and back to the sump again. The results of the tests with and without the oil cooler at a lower pressure drop than was used in the other tests are given in table I, runs 51 and 52. The oil-in temperature was decreased 40° F and the flange temperature 9° F, compared with the temperatures without the cooler. There were indications that the flange temperatures would decrease appreciably with a further decrease of oil temperature.

The baffles were then opened wide at the flanges (see point B, fig. 5) and another test was made with a low oil-in temperature (table I, run 54). The hottest flange temperature was decreased from 346° F, run 48, to 317° F with an oil-in temperature of 163° F and a cooling pressure drop of 7.5 inches of water. The hottest head temperature was only 483° F. A survey of top and bottom flange temperatures showed that all of the flanges were approximately 250° F except the bottom flanges of cylinders 2 and 4, which were a little above 300° F as shown for cylinder 4 in table I, run 54.

All temperatures were considered satisfactory and the rest of the tests were made with an oil-in temperature of approximately 165° F and with the baffle set-up as used in run 54.

PERFORMANCE AND COOLING TESTS

Engine Performance

The results of the tests with wide-open throttle for varying engine speed are given in figure 7. All values of mean effective pressure and horsepower are observed readings. The tests were conducted with the smallest quantity of cooling air possible for adequate cooling. The manifold pressure was less than atmospheric owing to the drop through the air-measuring system. The pressure decreased as the engine speed increased. For a given

manifold pressure and temperature, the brake mean effective pressure and the indicated mean effective pressure increased with an increase of speed within the range tested. The tests were made with a maximum power mixture and the results show that the indicated and the brake specific fuel consumptions and the fuel-air ratio remained constant over the range of speeds tested.

The variation of power, mean effective pressure, and specific fuel consumption with fuel-air ratio at wide-open throttle and at an engine speed of 2600 rpm is shown in figure 8. The power is a little greater in figure 8 at the maximum-power mixture than that given in figure 7 at 2600 rpm. This difference is due to the fact that the engine was a little cooler in the fuel-air-ratio tests than in the speed tests. The power remains fairly constant for fuel-air ratios from 0.07 to 0.085 but below 0.07 it rapidly decreases.

The fuel consumption for a fuel-air ratio of 0.069 will be used hereinafter to denote the maximum-economy mixture even though the minimum specific fuel consumption is obtained with a fuel-air ratio of 0.065. The ratio used will be 0.069 instead of 0.065 because there is little difference in the specific fuel consumption with either ratio, and the power is appreciably greater with the higher ratio.

The results of the tests to determine whether to use a small or a large amount of cooling air are shown in figure 9 for maximum-power and maximum-economy mixtures. The engine was operated at wide-open throttle and 2600 rpm. The curves show that, as the pressure drop across the baffles is increased, the net power (brake power minus blower power) at the maximum-power mixture increased a little and then decreased slightly. For the maximum-economy mixture the net power slightly decreased. The temperatures appreciably decreased with an increase in pressure drop. Because the net power is about the same with a high pressure drop as with a low pressure drop and because the engine is much cooler, which is advantageous for long life, the conclusion can be drawn that it is better to use as much air as possible without requiring wing ducts of such size as to interfere with the aerodynamic characteristics of the wing. When a low pressure drop is used, the maximum head temperature is about 500° F and the engine is called hot. When a higher pressure drop is used to reduce the maximum cylinder temperature to about 450° F, the engine is called warm.

The blower power was based on 100-percent blower ef-
ficiency because efficiencies of wing ducts as high as
100 percent are quite possible. This phenomenon is caused
by the fact that flow through such ducts sometimes affects
the external flow about the wing in a beneficial manner.
The efficiency is the ratio of the power required to force
the air across the engine to the power required due to the
change in drag of the wing with the wing duct. If hot air
is used, the "Meredith effect" will increase the over-all
efficiency to something greater than 100 percent.

Tests were made with a standard commercial fuel of
78 octane number to compare the performance of the engine
with the performance with 100 octane fuel, the spark set-
ting being the same for both fuels. Tests were conducted
with a wide-open throttle for each fuel with a hot and a
warm engine. In addition, tests were made with a warm
engine with the manifold pressure equal to the standard
pressure at 8000 feet altitude. The results of the tests
are given in table II.

The values of horsepower with wide-open throttle are
observed values and those at part throttle have been cor-
rected to the temperature at 8000 feet. With wide-open
throttle the power decreased approximately 2.5 percent
when 78 octane fuel was used as compared with the power
when 100 octane fuel was used. With part-throttle opera-
tion the power remained the same. The decrease with wide-
open throttle is possibly due to the lower volatility of
the 78 octane fuel as compared with the 100 octane fuel.
At full throttle the 100 octane gasoline is probably al-
most completely evaporated, whereas the 78 octane gaso-
line is only partly evaporated. At part throttle the de-
crease in manifold pressure will increase the percentage
of 78 octane gasoline evaporated to almost 100 percent
and will thus cause the power developed by the two fuels
to be nearly equal.

Engine Cooling

By means of the tests varying in turn the pressure
drop across the engine and the indicated horsepower, and
with all other engine and cooling conditions constant,
equations for the average head and barrel temperatures of
the engine were obtained. The temperature data on cylin-
ders 1 and 4 were used to determine the average temperature

because there was very little difference in the cooling of the two cylinders. The methods of obtaining the equations are given in reference 1. The tests were conducted with maximum-power mixture, and T_g for the head was assumed to be 1150° F and for the barrel, 600° F. For the head the equation is

$$\frac{T_h - T_a}{T_g - T_h} = 0.031 \frac{I^{0.69}}{\left(\Delta p \rho / \rho_o\right)^{0.37}} \tag{3}$$

and for the barrel,

$$\frac{T_b - T_a}{T_g - T_b} = 0.075 \frac{I^{0.66}}{\left(\Delta p \rho / \rho_o\right)^{0.51}} \tag{4}$$

From the equations and the tests in which all of the engine and cooling conditions except fuel-air ratio were kept constant, the effective gas temperature was calculated for each fuel-air ratio. The results are shown in figure 10 for the head and the barrel.

The cooling data for the tests made to establish the equation for average head and barrel temperatures and for the tests to determine the net power with maximum-power and maximum-economy mixtures are correlated in figure 11.

The ratios $\dfrac{T_b - T_a}{T_g - T_b}$ and $\dfrac{T_h - T_a}{T_g - T_h}$ are plotted against

$\dfrac{I^{1.294}}{\Delta p \rho / \rho_o}$ and $\dfrac{I^{1.87}}{\Delta p \rho / \rho_o}$, respectively. The ratio $\dfrac{n'}{m}$ for

the head is 1.87 and for the barrel is 1.294. The values of T_g for the various fuel-air ratios were obtained from figure 10. The head data fall around a single line for all the tests, as would be expected. Similarly, a single line represents all the barrel data.

With the exponents of equation (3), the data for the hottest head temperature (on cylinder 4 at the same location as thermocouple 14, fig. 5) have been correlated in

figure 12 by plotting the left-hand side of equation (2) against $\Delta p\rho/\rho_0$. The scatter of the data was found to be haphazard and no trend with any of the variables could be observed. The data for the hottest barrel temperature (on cylinder 4 at the same location as thermocouple 4, fig. 5) were plotted similarly in figure 12, the exponents of equation (4) being used. For both head and barrel temperatures, $f_1 (\Delta p\rho/\rho_0)$ in equation (2) can be replaced by constants that agree with former correlations of individual temperature data (reference 2). Although some of the data of figure 12 seem to be rather far from the curves, the lines drawn represent the data very well. For instance, the temperature at the point farthest from the curve of head temperatures is only 3° F different from the temperature calculated by means of the equation derived from the curve.

The flange temperatures of cylinders 1 and 4 are plotted against average barrel temperatures in figures 13 and 14, respectively. A line drawn (fig. 13) to represent a 1:1 ratio of flange temperature to average barrel temperature represents the data for cylinder 1 accurately enough for all practical purposes. The flange temperature of cylinder 4, however, was greater than the average barrel temperature and did not vary directly with the barrel temperature, as shown in figure 14. The flange temperature of cylinder 3 was approximately the same as that of cylinder 1, and the flange temperature of cylinder 2 was a little less than that of cylinder 4. It is therefore possible, from equation (4) and figures 13 and 14, to predict the flange temperatures of the four cylinders for all engine and cooling conditions.

The quantity of cooling air passing across the cylinders during the final performance and cooling tests is given in figure 15 for various pressure differences. All the data taken fall along a single line, as would be expected.

PERFORMANCE AND COOLING AT ALTITUDE

From the foregoing tests the performance and the cooling characteristics of the engine at an altitude of 8000 feet have been calculated for wide-open throttle and an engine speed of 2600 rpm. The engine is assumed to be

operated under such conditions in the projected airplane.
The curves in figure 7 showed that, with a maximum-power
mixture, 66.5 brake horsepower was developed at 2600 rpm
and wide-open throttle, at the manifold pressure and tem-
perature given in the figure. The back pressure was 1
inch of mercury and the engine was hot. The power at
8000 feet for a hot engine was then determined by the
formula that power varies directly as the manifold pres-
sure and inversely as the square root of the absolute
manifold temperature. For low altitudes this approximate
formula predicts power within a few percent of that pre-
dicted by more exact formulas. The manifold pressure and
temperature at altitude were assumed to be that of the
standard atmosphere (reference 4). The brake horsepower
at altitude with a warm engine was determined by assuming
that the variation of power with engine temperature was
the same at altitude as it was in the laboratory tests.

The fuel-air ratio and the indicated specific fuel
consumption for maximum-power mixture with wide-open
throttle at altitude were assumed to be the same as in
the tests with wide-open throttle in the laboratory. A
test was made in the laboratory to check this assumption
by operating the engine at the same calculated power out-
put obtained with maximum-power mixture at 8000 feet.
The indicated fuel consumption for a given fuel-air ratio
under these conditions was practically the same as at
wide-open throttle in the laboratory. The tests with a
hot and a warm engine showed that the indicated fuel con-
sumption and the fuel-air ratio remained constant. The
assumption was made that such would be the case at alti-
tude. From the assumption that the mechanical efficiency
at 8000 feet was the same as at sea level, and the brake
horsepower and the indicated fuel consumption at altitude
being known, it was also possible to calculate the brake
fuel consumption.

The pressure drop required to cool the engine at the
calculated power output at 8000 feet with a hot engine
was obtained by means of the equation for the hottest head
temperature, which was taken as 500° F. The cooling-air
temperature was obtained from the standard atmosphere
tables (reference 4), and the effective gas temperature
was read from figure 10. The pressure drop being known,
the hottest barrel temperature and the average barrel tem-
perature were calculated by means of the equations previ-
ously mentioned. The flange temperatures were obtained

from figures 13 and 14, and the cooling-air weight was ob-
tained from figure 15. With the warm engine at altitude
the assumption was made that the variation of the average
barrel temperature with the hottest head temperature was
the same at altitude as it was in the laboratory tests.
The average cylinder temperature with the warm engine be-
ing known, the pressure drop and the other pertinent tem-
peratures could be obtained by means of the equations and
the curves. The performance and the cooling characteris-
tics at 8000 feet with the maximum-economy mixture and at
sea level with the maximum-power mixture were determined
in like manner.

The results of the calculations are shown in figures
16, 17, and 18. At altitude a very low pressure drop can
be used with adequate cooling. The quantity of cooling
air required is also low enough so that it can be supplied
by means of ducts in the wing. More pressure drop would
be needed for cooling at sea level than at altitude but
would be needed only for a short time during take-off.
The results of figures 16, 17, and 18 show that it is per-
fectly feasible from cooling considerations to install
these air-cooled engines in the wings of airplanes.

MODIFIED MANIFOLD TESTS

The carburetor of the Continental engine is mounted
below the engine, as shown in figure 19(a). In order to
install the engine in the small space provided in the wing
of an airplane, the carburetor had to be relocated and the
manifolds redesigned. Several arrangements of the mani-
fold piping and the carburetor location were tried before
an acceptable modification was obtained. It was found
that the slope of section A (fig. 19(b)) should be gradual
and that the junction point B should be as close to the
carburetor as possible. Any deviation from this arrange-
ment caused backfiring and rough running, which was par-
ticularly noticeable when 78 octane gasoline was used and
when the mixture was leaned. The best results were ob-
tained with the modification shown in figure 19(b).

With a maximum-power mixture and 100 octane fuel,
the performance with this modification of the manifolds
was a little better, about 2 horsepower, than with the
standard manifolds over a range of speeds from 1600 to

2600 rpm. With 78 octane fuel the performance at some speeds was slightly better than, and at other speeds was equal to, the performance with the standard manifolds and 100 octane fuel. When the mixture was leaned, with this modification to the manifolds, the performance at 2600 rpm with either 100 octane or 78 octane fuel compared favorably with that using the standard manifolds and 100 octane fuel.

The starting ability of the engine was checked with these modified manifolds using 78 octane gasoline. The control positions of the dynamometer were so set that the maximum motoring speed was 250 rpm. Voltage was applied to the dynamometer and, as soon as the dynamometer started to turn, the voltage was discontinued; during the interval of time that the engine continued to rotate, an attempt was made to start it. While the engine was cold, starting was difficult under these conditions because it was necessary for the engine to turn over several times to fill the fuel line and the float chamber. The engine was started on the fourth attempt, and each subsequent attempt succeeded. After the first successful attempt at starting, the firing began at the end of the second revolution of the engine. The difficulties encountered during the first attempts probably could be eliminated by using an efficient priming system.

CONCLUSIONS

From the results obtained in laboratory tests of a Continental A-75 engine it was found that

1) The engine could be cooled satisfactorily at sea level with wide-open throttle and maximum-power mixture with a pressure difference of 4.5 inches of water and 1.06 pounds of cooling air per second.

2) From data obtained in tests on the ground, calculations showed that satisfactory cooling could be obtained at an altitude of 8000 feet with wide-open throttle and either maximum-power or maximum-economy mixture with a pressure difference of 2.6 inches of water and approximately 0.75 pound of cooling air per second.

3) The net brake horsepower obtained (brake horse-
power of engine minus power required for cool-
ing) remained approximately constant at wide-
open throttle for a range of cooling-pressure
differences.

4) For satisfactory cooling an oil cooler would be
required to maintain the oil temperature at
approximately 165° F.

5) The power obtained with the modified intake mani-
folds, which were designed to reduce the over-
all thickness of the engine to that of the
crankcase, compared favorably with the power
obtained with the original manifolds.

Langley Memorial Aeronautical Laboratory,
    National Advisory Committee for Aeronautics,
        Langley Field, Va., May 6, 1941.

REFERENCES

1. Pinkel, Benjamin: Heat-Transfer Processes in Air-
    Cooled Engine Cylinders. Rep. No. 612, NACA, 1938.

2. Pinkel, Benjamin, and Ellerbrock, Herman H., Jr.:
    Correlation of Cooling Data from an Air-Cooled
    Cylinder and Several Multicylinder Engines. Rep.
    No. 683, NACA, 1940.

3. Schey, Oscar W., Pinkel, Benjamin, and Ellerbrock,
    Herman H., Jr.: Correction of Temperatures of Air-
    Cooled Engine Cylinders for Variation in Engine
    and Cooling Conditions. Rep. No. 645, NACA, 1938.

4. Diehl, Walter S.: Standard Atmosphere - Tables and
    Data. Rep. No. 218, NACA, 1925.

TABLE I

RESULTS OF TESTS WITH PRELIMINARY BAFFLES

Run	Cooling system	Power (ihp)	Engine speed (rpm)	$\Delta p \rho / \rho_0$ (in. water)	Cooling-air weight (lb/sec)	Oil-in temperature ($^\circ$F)	Hottest head temperature ($^\circ$F)	Hottest barrel temperature ($^\circ$F)	Hottest flange temperature ($^\circ$F)	Cooling-air temperature ($^\circ$F)
36	Preliminary baffles	78.5	2600	7.3	1.58	212	493	362	350	94
47	Welded baffles	75.4	2570	6.8	1.38	202	493	354	348	110
48	Leaks in rocker boxes sealed	79.4	2610	7.5	1.34	217	496	346	343	94
51	Without oil cooler	77.5	2618	5.7	1.14	240	521	368	360	100
52	With oil cooler	76.9	2630	5.8	1.15	200	519	362	351	98
54	Baffles opened at flanges	75.1	2598	7.5	1.38	163	483	334	317	96

TABLE II

RESULTS OF TESTS ON FUELS OF DIFFERENT OCTANE NUMBERS

[Engine speed, 2600 rpm]

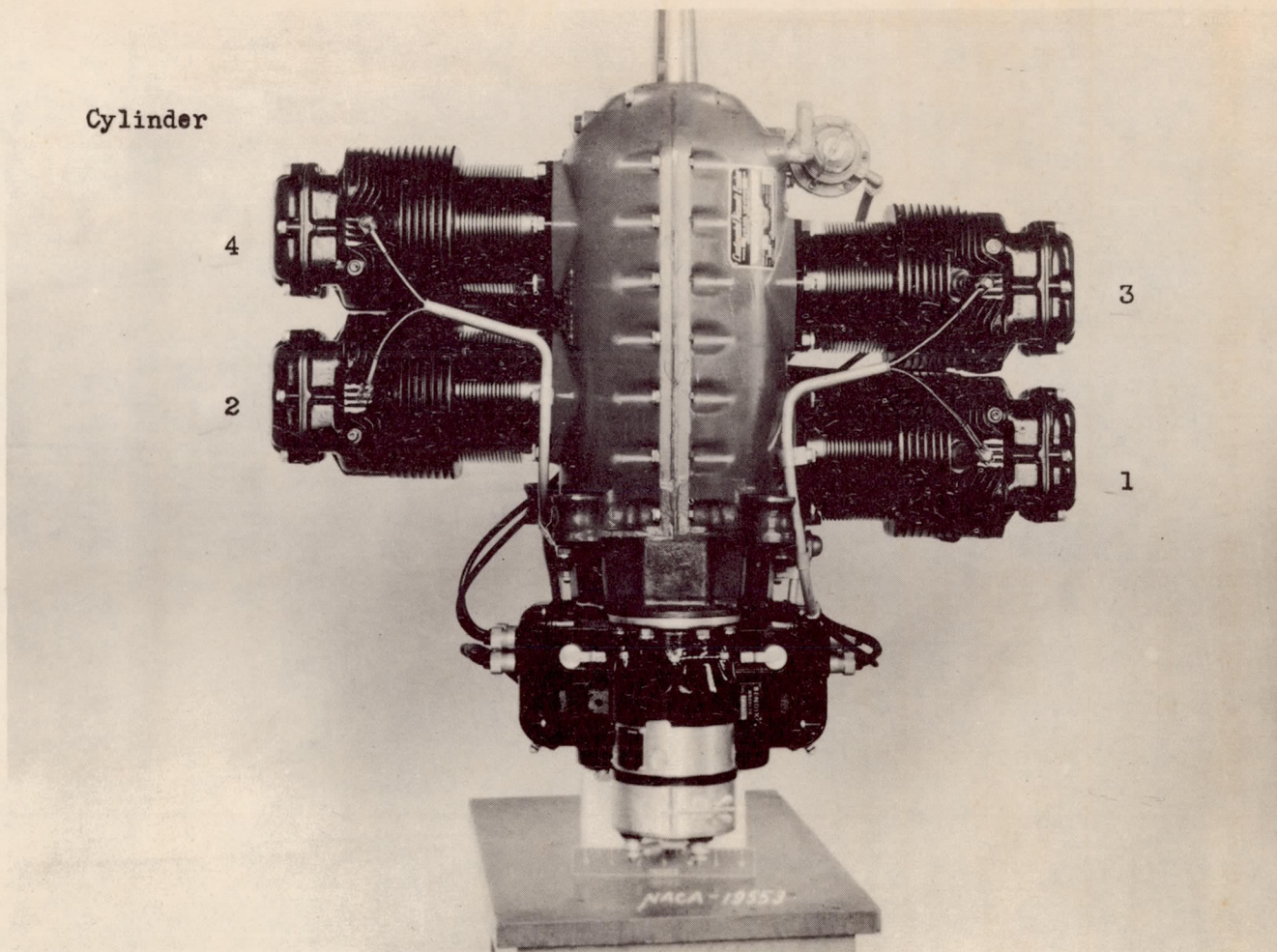| Engine condition	Octane number of fuel	Throttle setting	imep (lb/sq in.)	Brake horse-power	Hottest head tem-perature (^{O}F)	Average cylin-der tem-perature (^{O}F)
Warm ----	100	Wide open	115.7	65.0	439	286
Do -------	78	- - do - -	112.2	63.0	436	276
Hot -----	100	- - do - -	113.2	63.6	490	313
Do -------	78	- - do - -	110.6	62.0	504	304
Warm ----	100	Part throttle	89.6	50.5	408	253
Do -------	78	- - do - -	89.6	50.5	420	265

Cylinder

Figure 1.- Top view of Continental A-75 engine.

Fig. 1
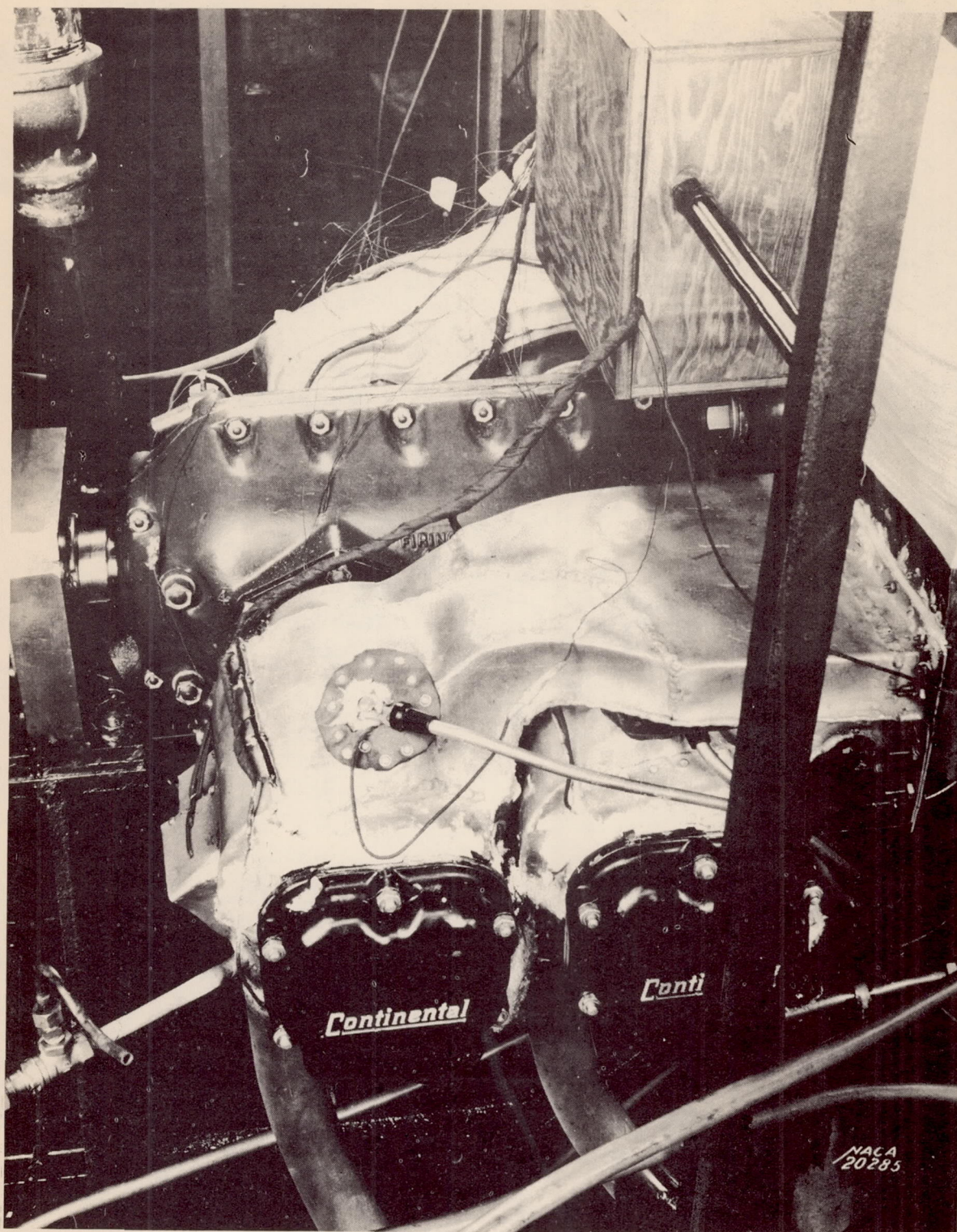
Figure 2.- Baffles used on Continental A-75 engine.

Fig. 3
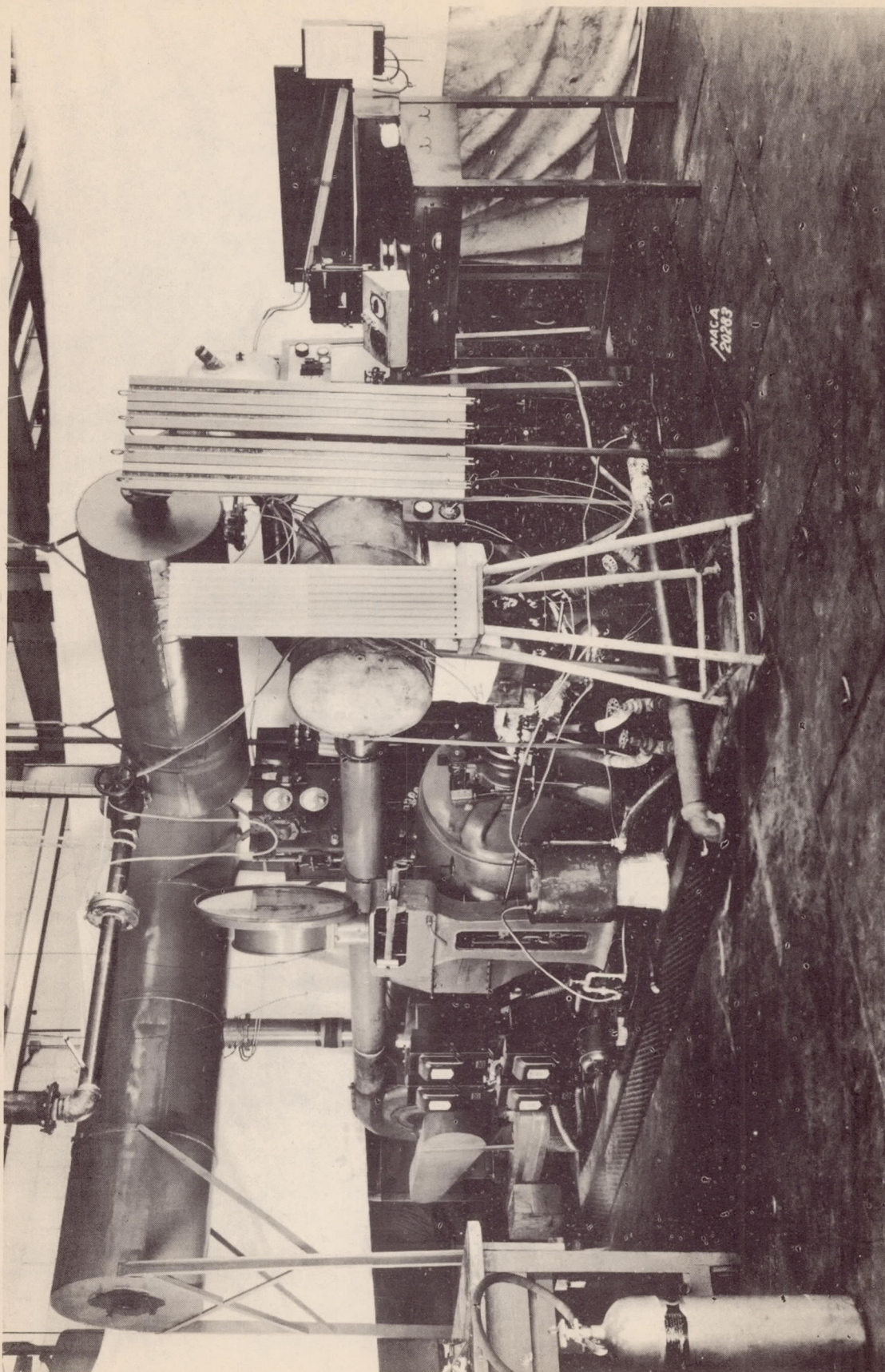
Figure 3.— Set-up of apparatus.
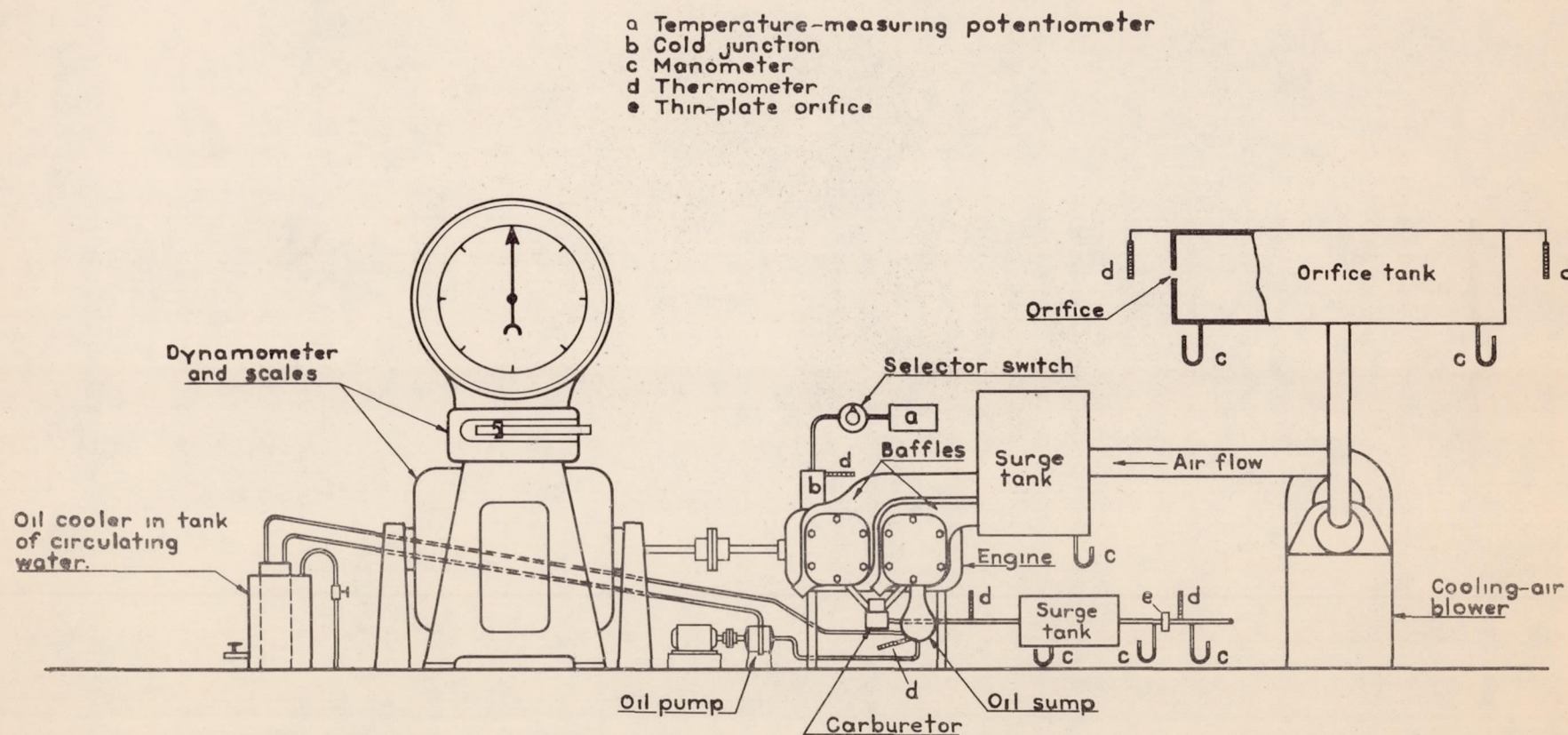
a Temperature-measuring potentiometer
b Cold junction
c Manometer
d Thermometer
e Thin-plate orifice

Orifice tank

d

Orifice

c U   c U

Selector switch

Dynamometer
and scales

a

d   Baffles

b

Surge
tank

Air flow

Oil cooler in tank
of circulating
water.

Engine U c

d   Surge
tank

e d

Oil pump

d

Carburetor

Oil sump

U c   c U   U c

Cooling-air
blower

Figure 4.- Diagrammatic sketch of set-up.

Fig. 4

Fig. 5

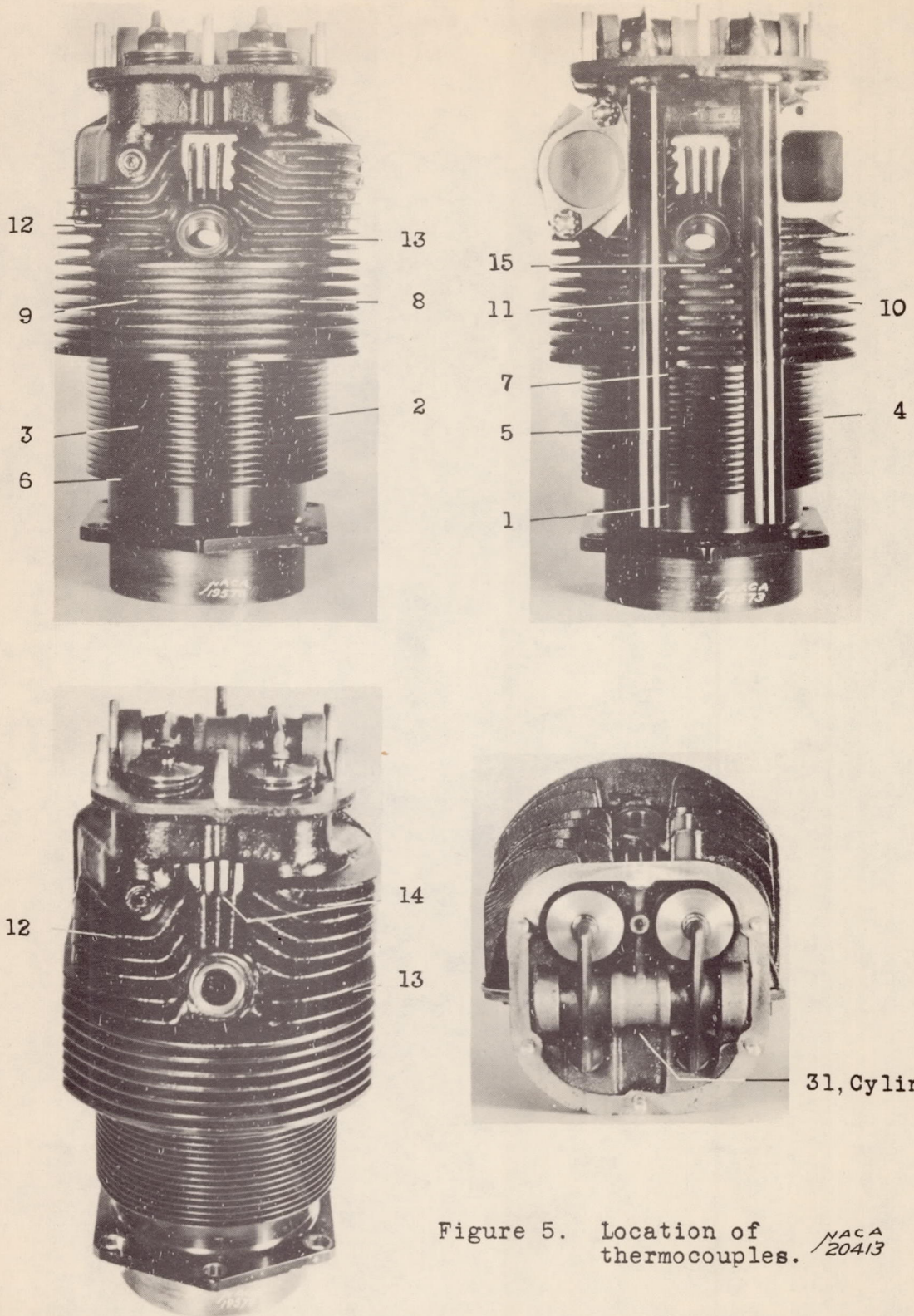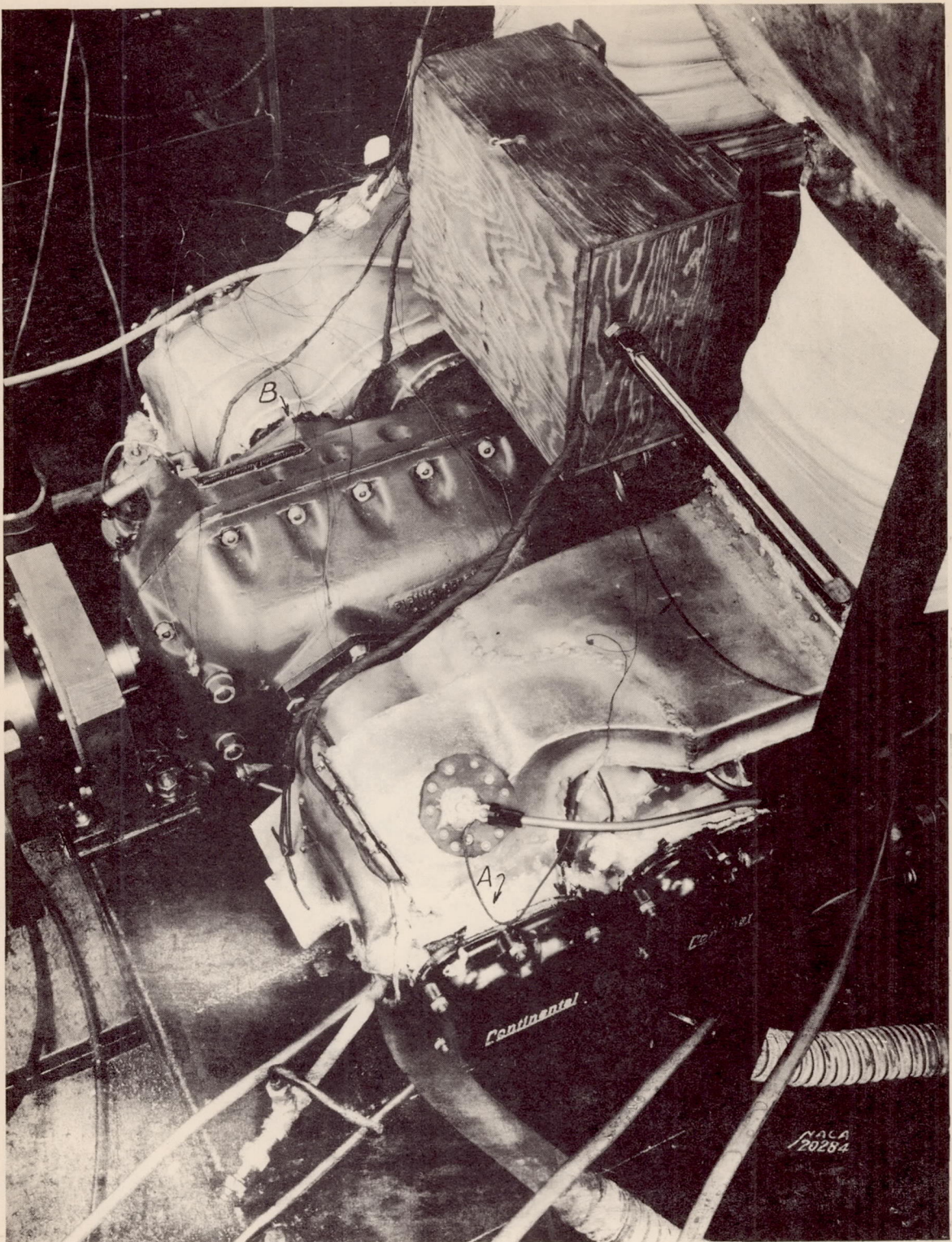Figure 5. Location of thermocouples.

Fig. 6
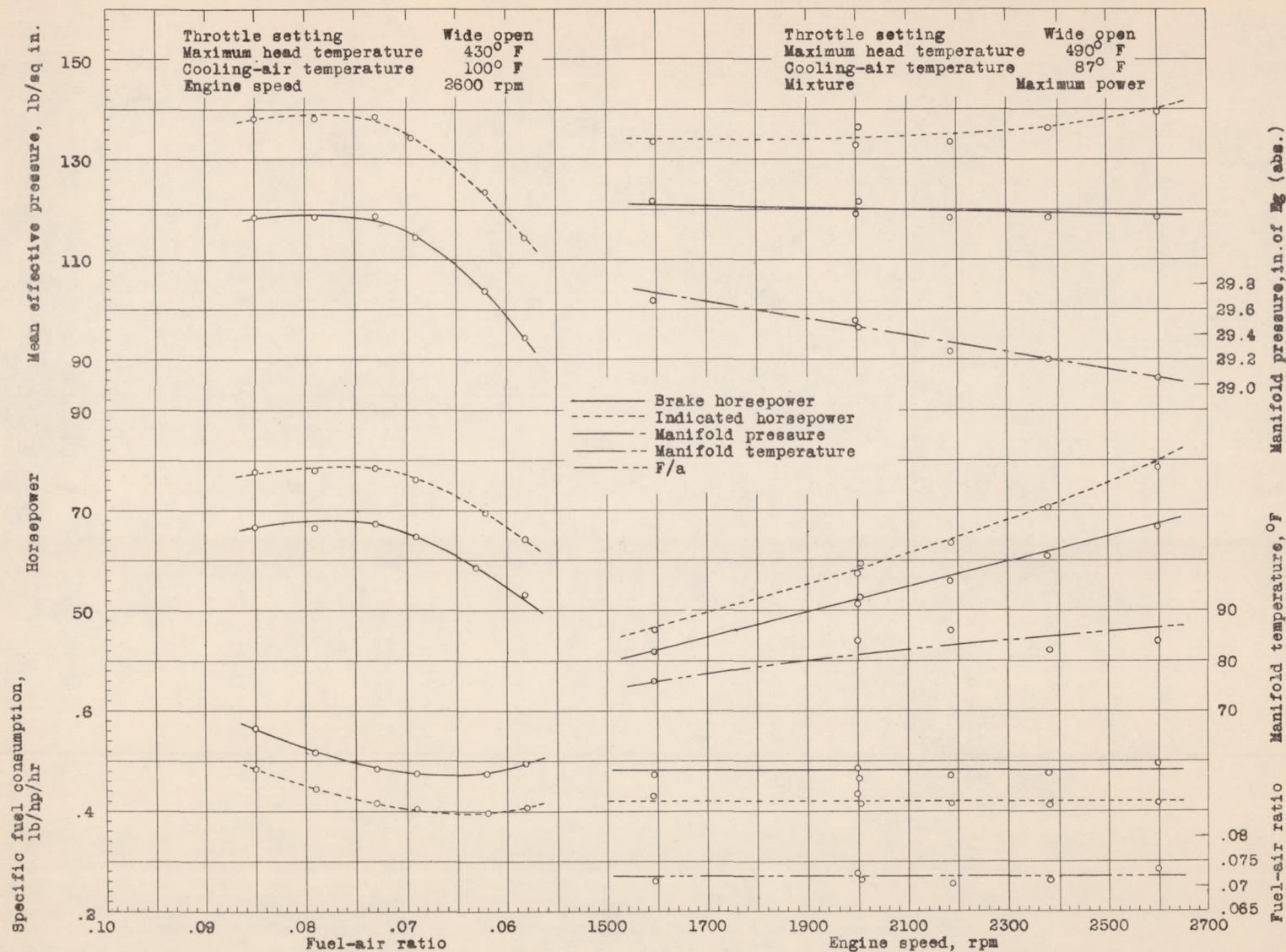

Figure 6.- Top view of baffles.

Figure 8.- Variation of performance with fuel-air ratio.

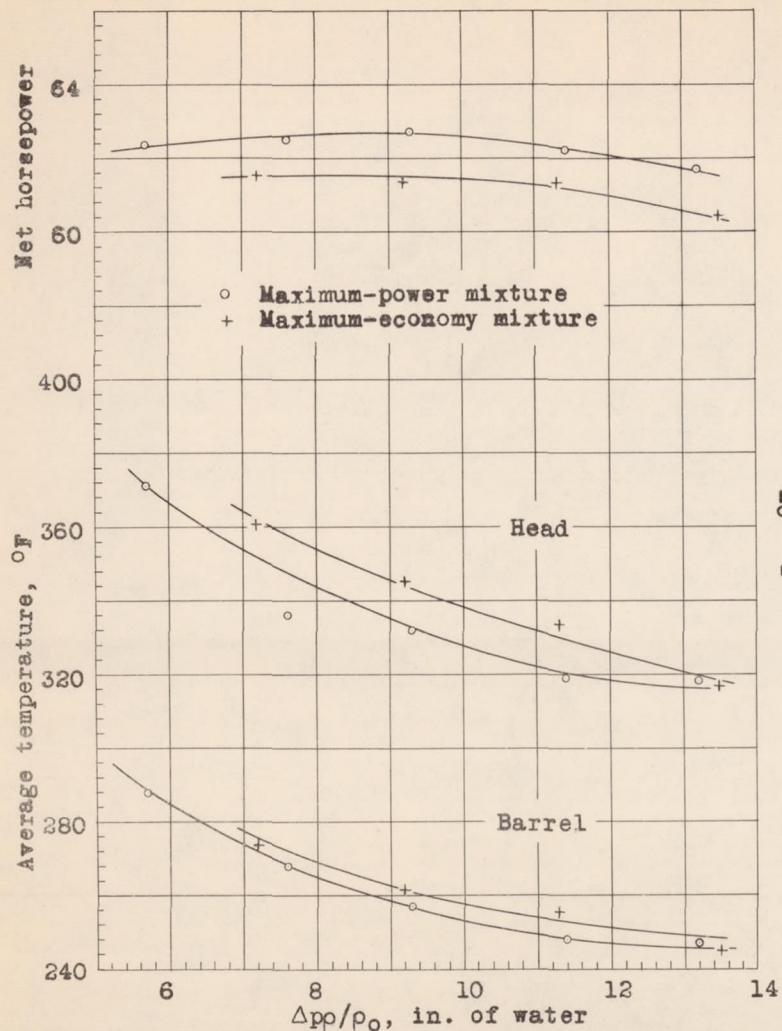Figure 7.- Variation of performance with engine speed.

Figure 9.- Net power obtained with various cooling pressure differences with wide-open throttle at 2600 rpm.
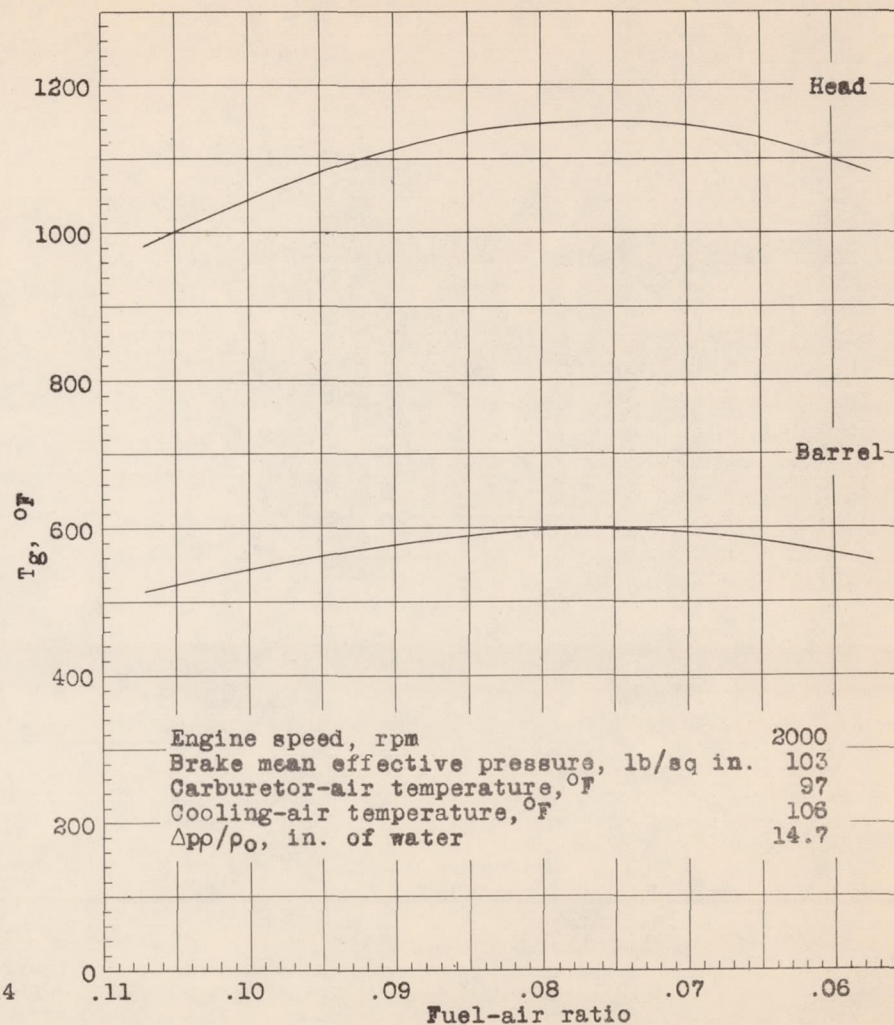

Figure 10.- Variation of the effective gas temperature with fuel-air ratio.

	+	O	△	□
Engine speed, rpm	2600	2600	2000	2600-1100
Brake mean effective pressure, lb/sq/in.	113-117	112-115	86	27-121
Fuel-air ratio	0.076	0.069	0.081	0.075
Carburetor-air pressure, in. of mercury	29	29	23	17-29
Carburetor-air temperature, °F	87	90	87	95
Cooling-air temperature, °F	100	106	81-109	103
$\Delta p\rho/\rho_0$, in. of water	4.7-13.2	7.4-13.5	1.6-13.1	13.5-14.2

$$\frac{T_b - T_a}{T_g - T_b}$$

$$\frac{T_h - T_a}{T_g - T_h}$$

Slope, 0.51

Slope, 0.37

(a)

(b)

$I^{1.294}/(\Delta p\rho/\rho_0)$

(a) Barrel

$I^{1.87}/(\Delta p\rho/\rho_0)$

(b) Head

$\frac{T_h - T_a}{T_g - T_h}$

$\frac{T_b - T_a}{T_g - T_b}$

Figure 11.- Correlation of cooling data.

Fig. 11

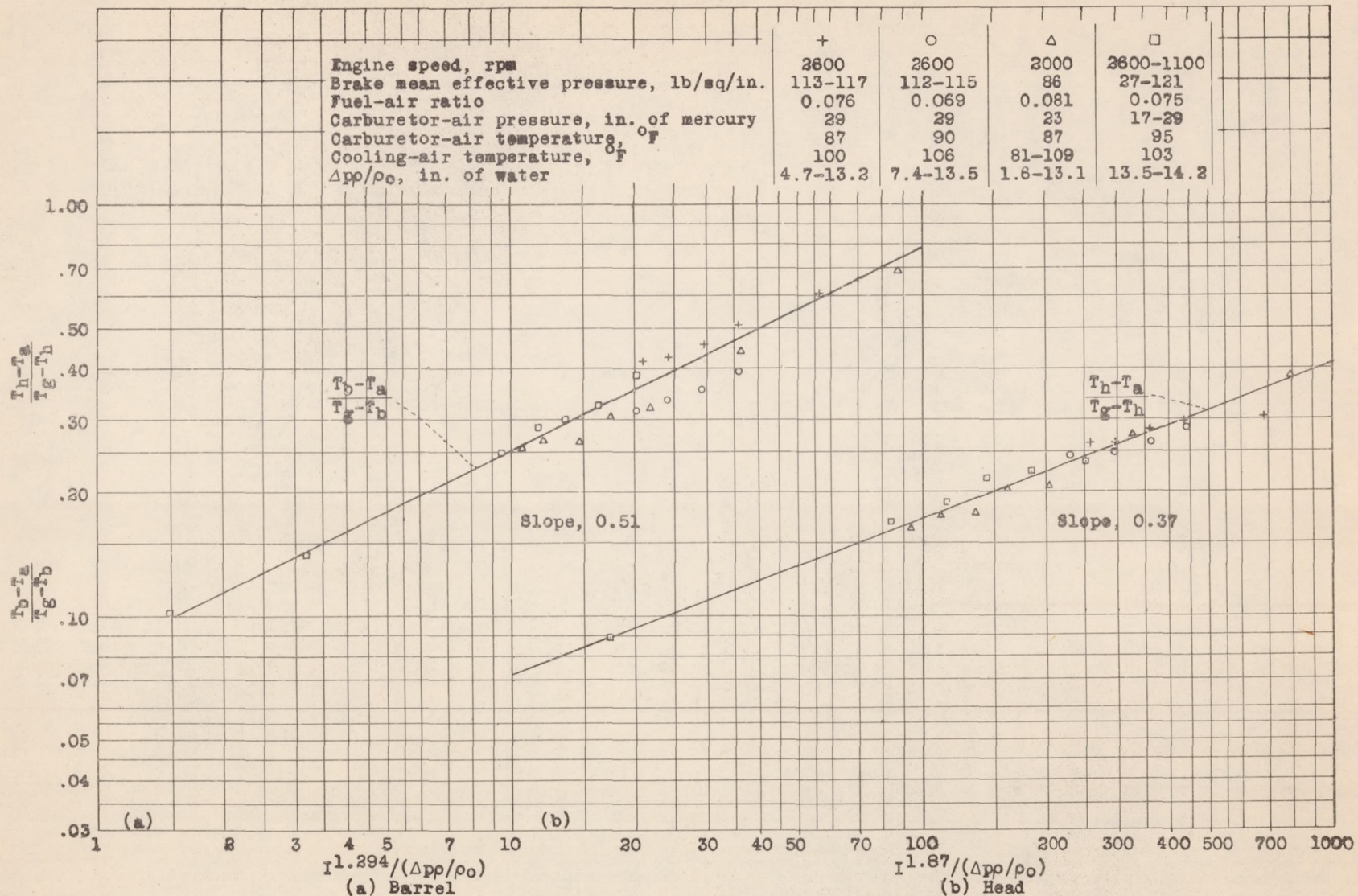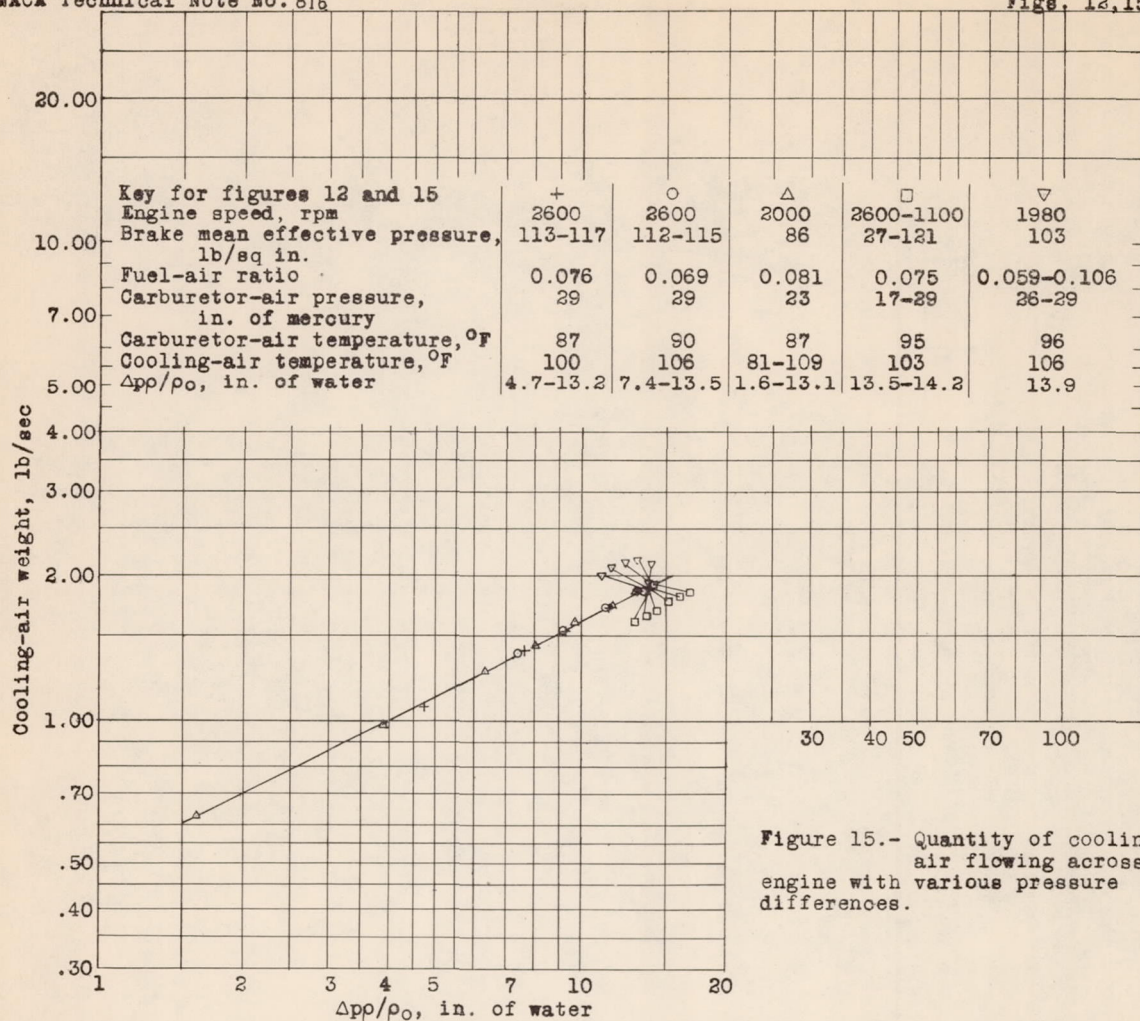| Key for figures 12 and 15	+	O	△	□	▽
Engine speed, rpm	2600	2600	2000	2600-1100	1980
Brake mean effective pressure, lb/sq in.	113-117	112-115	86	27-121	103
Fuel-air ratio	0.076	0.069	0.081	0.075	0.059-0.106
Carburetor-air pressure, in. of mercury	29	29	23	17-29	26-29
Carburetor-air temperature, °F	87	90	87	95	96
Cooling-air temperature, °F	100	106	81-109	103	106
$\Delta p \rho / \rho_0$, in. of water	4.7-13.2	7.4-13.5	1.6-13.1	13.5-14.2	13.9

Figure 15.- Quantity of cooling air flowing across engine with various pressure differences.
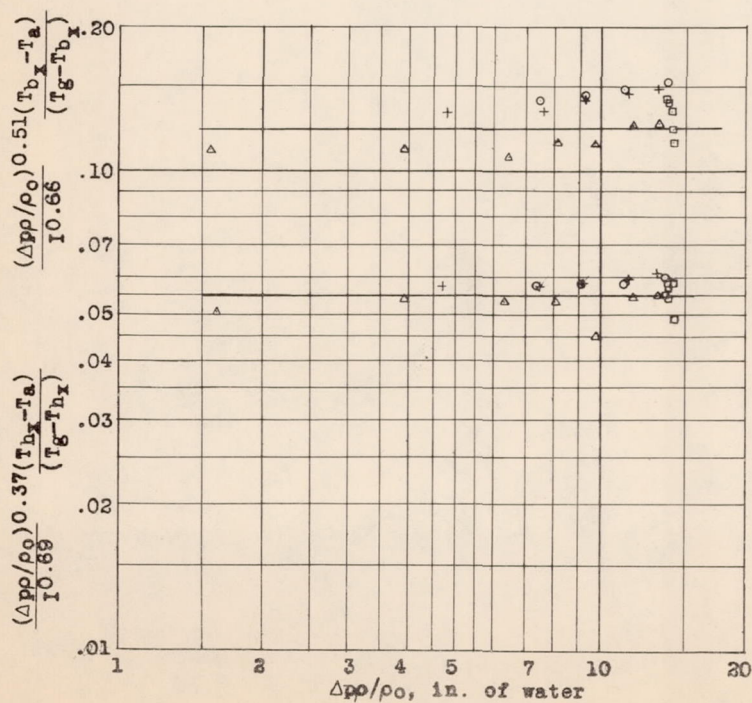
Figure 12.- Variation of hottest head and barrel temperatures with engine and cooling conditions.

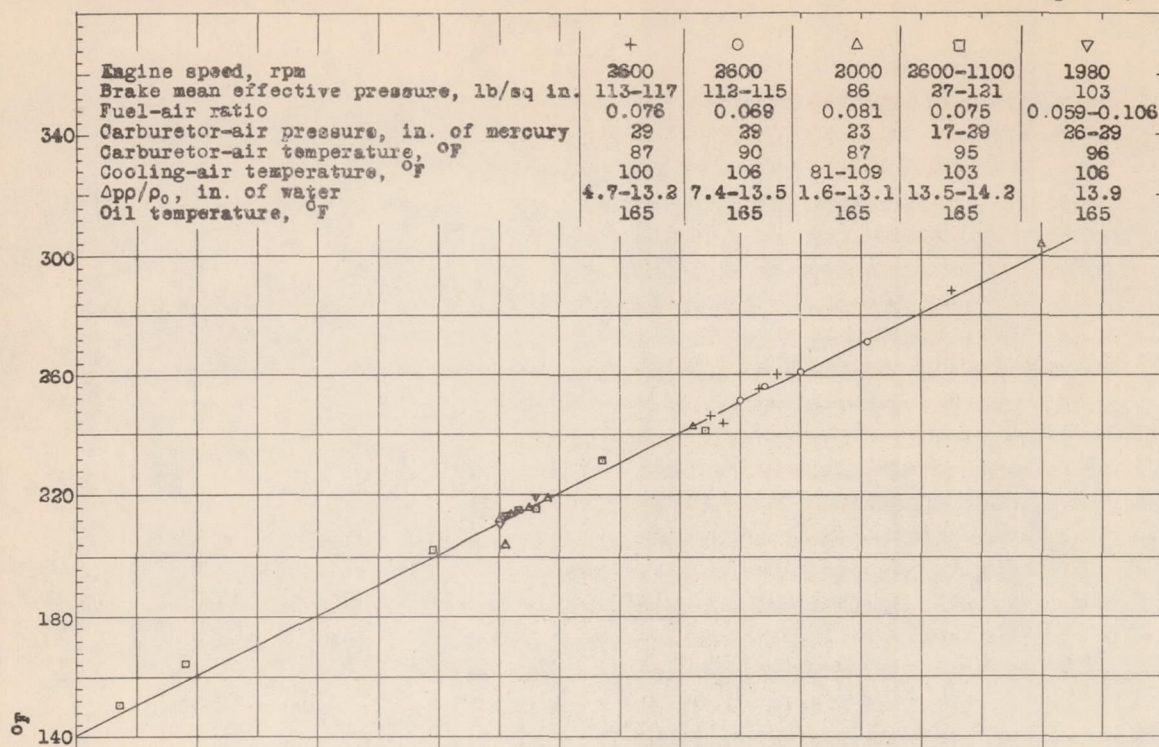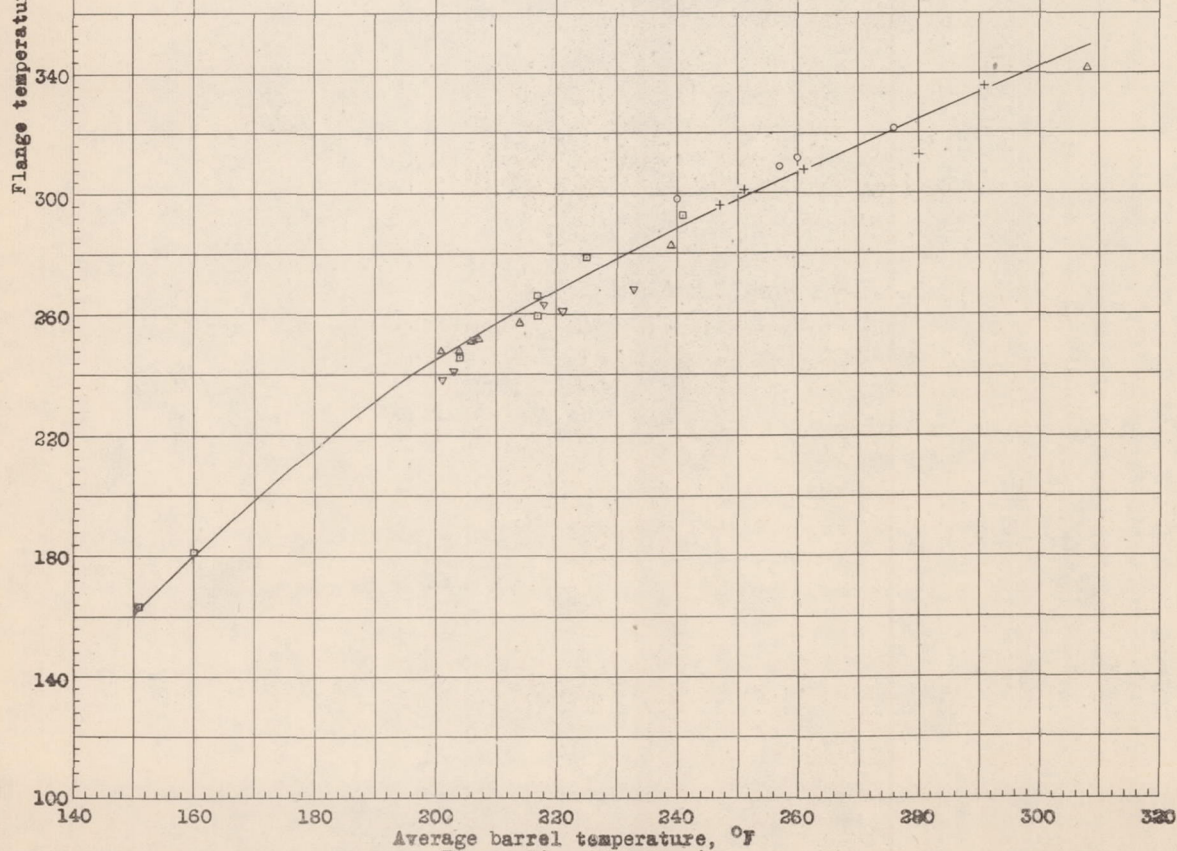|	+	○	△	□	▽
Engine speed, rpm	2600	2600	2000	2600-1100	1980
Brake mean effective pressure, lb/sq in.	113-117	112-115	86	27-131	103
Fuel-air ratio	0.076	0.069	0.081	0.075	0.059-0.106
Carburetor-air pressure, in. of mercury	29	39	23	17-29	26-29
Carburetor-air temperature, $^{\circ}F$	87	90	87	95	96
Cooling-air temperature, $^{\circ}F$	100	106	81-109	103	106
$\Delta p \rho / \rho_0$, in. of water	4.7-13.2	7.4-13.5	1.6-13.1	13.5-14.2	13.9
Oil temperature, $^{\circ}F$	165	165	165	165	165

Figure 13.- Cylinder 1

Figure 14.- Cylinder 4

Figures 13 and 14.- Variation of the flange temperatures of cylinders
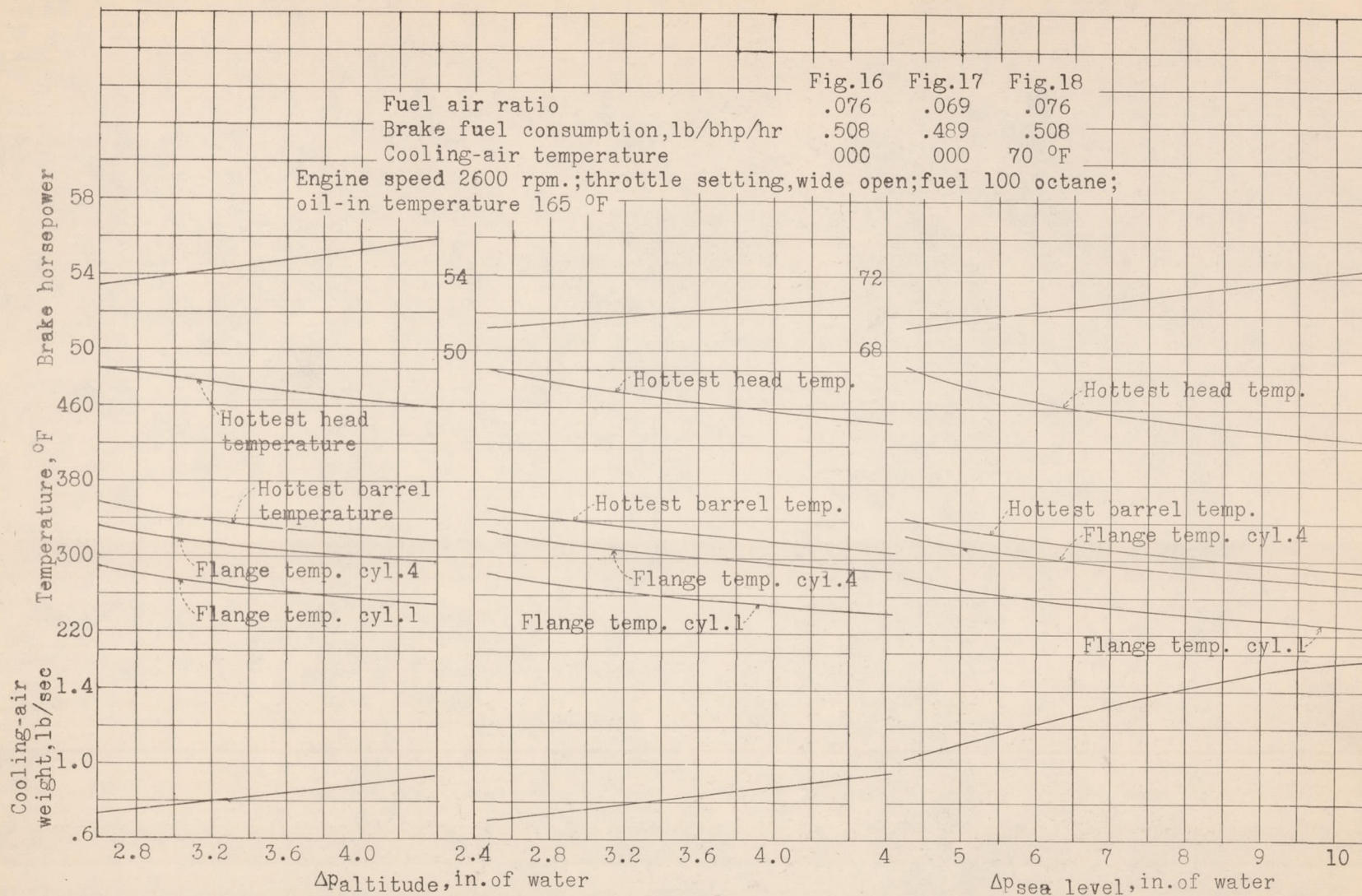1 and 4 with the average barrel temperatures.

	Fig.16	Fig.17	Fig.18
Fuel air ratio	.076	.069	.076
Brake fuel consumption, lb/bhp/hr	.508	.489	.508
Cooling-air temperature	000	000	70 °F

Engine speed 2600 rpm.; throttle setting, wide open; fuel 100 octane; oil-in temperature 165 °F

Figure 16.-Max.power mixture.   Figure 17.-Max.economy mixture.

Figures 16 and 17.- Performance and cooling characteristics of engine at 8000 feet altitude.

Figure 18.-Max.power mixture.

Figure 18.-Performance and cooling characteristics of engine at sea level with maximum-power mixture.
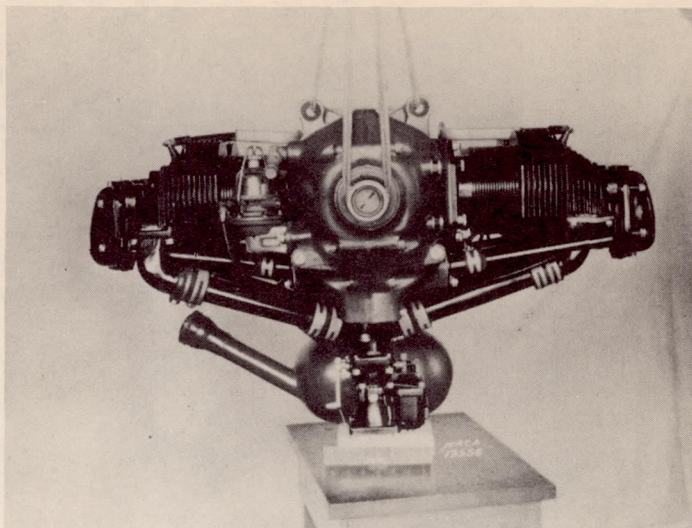
(a) Standard manifolds.
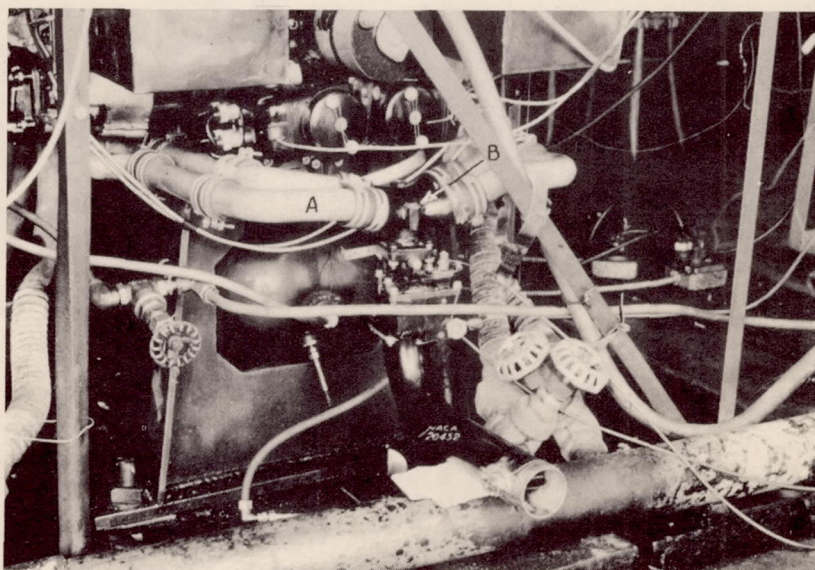
(b) Modified manifolds.

Figure 19.- Various intake manifold systems tested.